Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

ON CRITICAL PERIODS IN THE HISTORY OF THE EARTH, AND THEIR RELATION TO EVOLUTION; ON THE QUARTERNARY AS SUCH A PERIOD.[1]

BY JOSEPH LECONTE.

IN the series of rocks representing the history of the earth there occur at different horizons *unconformities.* In most cases these are not found at the same horizon in different places; but there are a few which seem to be very general. Associated with these unconformities, as is well known, there is nearly always a marked change in the fossil species. The greatness of this change is invariably in direct proportion to the generality of the unconformity. These general unconformities attended with very great changes in organic forms are the natural boundaries of the great divisions of time, and the less general unconformities attended with less sweeping change of organic forms, of the subdivisions of time.

The earlier geologists, under the influence of the *then* dominant idea of frequent supernatural interference with the course of nature, imagined that these unconformities marked the times of instantaneous cataclysm which disturbed the rocks and destroyed all living things, sometimes locally, sometimes generally, and that these exterminations were followed by re-creations of other and wholly different species at the beginning of the subsequent period of tranquillity. *Now*, however, we believe that no such instantaneous general exterminations and re-creations ever occurred. We know that unconformity simply indicates eroded land-surface, and therefore marks a period of time during which the observed place was land and received no sediment; that two series of rocks unconformable to each other denote two periods of comparative quiet, during which the observed place was sea-bottom, receiving sediment steadily, separated by a period of oscillation producing increase and decrease of land, during which the observed place was raised into land-surface, with or without crumpling of the strata, deeply eroded, and then sunk again below sea level to receive the second series of strata. The length of the two periods of repose is roughly measured by the thickness of the two conformable series. The length of the period of commotion is roughly measured by the amount of erosion at the line of unconformity.

---

[1] Read before the National Academy of Sciences, April 18, 1877. (Reprinted from the American Journal of Science and Arts, for August, 1877.)

Evidently, therefore, every case of unconformity marks a period of time — often a long period — during which there was no record made in strata and fossils at the observed place; certain leaves — frequently very many — are there missing from the Book of Time. Is it any wonder, then, that skipping over these pages when we commence reading again we find the matter entirely new? Evidently, the suddenness of the change in organic forms is only apparent. If we could recover the record, which was doubtless carried on elsewhere, the break would disappear; if we could find the missing leaves the reading would be continuous. In every such instance, therefore, there is a *lost interval* of history. In cases of local unconformity we recover the lost record in other places, and thus fill up the blank in the history. But in some cases of very general unconformity, such as those which mark the great divisions of time, the loss is not yet recovered, perhaps is irrecoverable, though doubtless the more complete knowledge of the geology of the whole earth surface will go far toward filling blanks and making the record continuous.

The view above presented is now held by all geologists, but there seems to be danger, under the influence of the *now* dominant views of evolution, of erring on the other extreme. Assuming a *uniform rate* of evolution, many, it seems to me, commit the mistake of measuring the amount of lost interval by the amount of change of organic forms, and thus discredit the real value of the geological record by exaggerating greatly its fragmentary character. On the contrary, there appears good reason to believe that the evolution of the organic kingdom, like the evolution of society and even of the individual, has its periods of *rapid movement* and its intervals of *comparative repose* and readjustment of equilibrium. Geological history, like all other history, has its periods of comparative quiet, during which the forces of change are gathering strength, and periods of revolution, during which the accumulated forces manifest themselves in conspicuous changes in physical geography and climate, and therefore in rapid movement in the march of evolution of organic forms, — periods when the forces of change are *potential*, and periods when they become *active*. Conformable rocks represent the intervals of comparative quiet, during which organic forms are either permanent or change slowly; unconformity represents a time of oscillation, with increase and decrease of land, and therefore of rapid changes of physical conditions and correspondingly rapid movement in evolution. The general unconformities, of course, mark times of very general commotion, — of wide-spread changes of physical geography and climate, and consequently of exceptionally rapid and profound changes in organic forms.

These periods of revolution in all history are *critical*, and hence are of especial interest to the philosophic historian and to the evolutionist; but they are also in all history periods of *lost record.* And as in human so also in geological history, — the farther back we go the longer are the lost intervals and the more irrecoverable the lost records. We will now give examples of such lost intervals, and show their significance in evolution.

The first and by far the greatest of these is that which occurs between the Archæan and the Palæozoic. In every part of the earth where the contact has yet been observed the Primordial lies unconformably on the upturned and eroded edges of the Archæan strata. This relation was observed first in Canada, then in various parts of the Eastern United States, then in Scotland, the Hebrides, Bavaria, Bohemia, Scandinavia. Unconformity in such widely separated localities indicates wide-spread changes in physical geography, and therefore, presumably, of all those physical conditions included in the word *climate.* These changes of physical geography are best illustrated in the United States. The break between the Archæan and the Primordial has been observed in very many places all over the wide area of the United States, east and west: not only in Canada, in New York, in the Appalachian region, in Wisconsin, Missouri, Arkansas, and Texas, but also all over the Rocky Mountain region, in Nebraska, Montana, Idaho, Wyoming, Colorado, Utah, Nevada, New Mexico, and Arizona. As upturned, eroded, outcropping strata mean land surface, it is evident that there was at that time *a very large area or else several large areas of land* in the place now occupied by the American continent. In comparison with the subsequent Silurian it was *a continental period.* This land is often spoken of as *Archœan land.* It was indeed land of *Archœan rocks*, but for that very reason not of Archæan times, for these rocks were, of course, formed at the bottom of the sea in Archæan times, and therefore these localities were all sea-bed receiving sediment at that time. We know absolutely nothing of the land of Archæan times, and never can know anything until we find still older rocks, from the *débris* of which Archæan sediment was formed. The land spoken of above was *land of the Lost Interval.* That the interval was immensely long is evident from the prodigious erosion. That it was a period of wide-spread oscillation is also apparent, for all the places mentioned were sea-bed in Archæan, land during the interval, and again sea-bed during the Silurian. But of this long interval not a leaf of record remains.

Evidently, then, at the end of the Archæan an enormous area of Archæan sea bottom was raised up and crumpled, and became land. After remaining land for a time sufficiently long to allow enormous erosion of crumpled strata it again went down to the old Primordial shore line, and the Silurian age commenced. This time of elevation is the lost interval.

Now, when the record closed in the Archæan, as far as we know, only the lowest forms of Protozoan life yet existed. The beginnings of life had not yet differentiated into what might be called a fauna and flora. When the record again opened with the Primordial we had already a varied and highly organized fauna, consisting of representatives of many classes and of all the great types of animal structure except vertebrates. Nor were these representatives the lowest in three several departments, for Trilobites and Orthoceratites can hardly be regarded as lower than the *middle of the animal scale* as it now exists. It is certain, therefore, that all the great departments except vertebrates, and most of the classes of these departments, including animals at least half-way up the animal scale, were differentiated during the lost interval. The amount of evolution during this interval cannot be estimated as less than all that has subsequently taken place. Measured by the amount of evolution, this lost interval is equal to all the history of the earth which has since elapsed. We escape this very improbable conclusion only by admitting *a more rapid rate of evolution during critical periods.*

It is one of the chief glories of American geology to have first established the Archæan as one of the primary divisions of time. It is even yet reluctantly admitted as such by many European geologists. And yet it is seen that from every point of view, whether of the rock system or of the life system, it is by far the most widely and trenchantly separated of all the eras.

The next greatest lost interval (though far less than the preceding) is that between the Palæozoic and the Mesozoic. Here we have the next most general unconformity, indicating the next most wide-spread changes of physical geography and climate, accompanied by the most sweeping changes in organic forms, not only in species and genera, but also in families and orders. This change is the more striking as it occurs in the midst of an abundant life. It is the greatest and most general change in the forms of organisms which has ever occurred in the history of the earth. *It took place, again, during a lost interval.* A portion of the loss is recovered in the Permian, but the most critical time, the time of most rapid change, namely, that between the Permian and the Trias, is still missing. How we long to find the steps of this great change! What a flood of light would it shed on the process of evolution! But although the change in the organic kingdom was, just here, so enormously great, yet the lost interval does not seem very long, for in England the Trias and Permian seem to be conformable, though probably with change from marine to fresh-water conditions. It is hence impossible to resist the conclusion that the steps were just here fewer and longer and the progress more rapid than usual. As in human history, revolutions are the times of the birth of new social ideas, upon which, during the subsequent period of tranquillity, society is readjusted in prosperity and happiness on a higher plane, so also in geological history, critical periods are times of origin of new and higher organic forms, and the subsequent periods of tranquillity are times of readjustment of equilibrium and prosperous development of these forms.

Like the previous lost interval, this was also a period of oscillation, — a period of great increase of land, which was again partly submerged to inaugurate the Trias. It was, therefore, also *a continental period.* The land-making commenced at the end of the Coal period, in this country with the formation of the Appalachian Mountains, continued through the Permian, and culminated in the lost interval, which is, in fact, for that very reason lost.

Far less in length of time and perhaps in the sweeping character of the change of organisms, but far more important and interesting on account of the high position of the animals involved, is the lost interval between the Mesozoic and Cænozoic. The length of time lost here is comparatively small. In America, in many parts of the West, the uppermost Cretaceous seems to pass into the lowermost Tertiary without the slightest break of continuity. There may be some break, some unconformity, some lost record, but certainly it cannot be large. Yet the change, especially in the higher animals, is immense. In America the break and the lost interval is much greater between the Jurassic and Cretaceous than between the Cretaceous and Tertiary, still the organic change is far greater in the latter case. The reason is that the changes of physical geography and climate in the latter were *more general.* Although in America the break and the lost interval is greater at the end of the Jurassic, yet, taking the strata all over the earth, the break is far more general at the end of the Cretaceous; and it is these *general* changes in physical geography which affect climate the most, and which, therefore, produce the profoundest changes in organic forms.

Now it is almost impossible to imagine a clearer proof of the fact of rapid evolution-movement during critical periods than we find in the shortness of the lost interval and the greatness of the change in higher organisms just at this horizon in the rocky series. Nothing can be more astonishing than the abundance, variety, and prodigious size of reptiles in America up to the very close of the Cretaceous, and the complete absence of all the grander and more characteristic forms in the lowest Tertiary, unless, indeed, it be the correlative fact of complete absence of mammals in the Cretaceous, and their appearance in great numbers and variety in the lowest Tertiary. If Cretaceous mammals existed in *America*, surely their remains would have been found in the wonderfully rich Cretaceous strata. It seems certain that in America, or at least in that portion which has been examined, mammals appeared somewhat suddenly and in great numbers on the scene, and were a principal agent in the extermination of the large reptiles. The wave of reptilian evolution had just risen to its crest, and perhaps was ready to break, when it was met and overwhelmed by the rising wave of mammalian evolution.

We have dwelt only on the great change in the higher classes, but the change really extended to all classes. This was, therefore, a time of exceptionally general and rapid changes in all departments alike. In other words it was a critical period in organic evolution.

That it was also a time of very extensive changes in physical geography here in America, as well as elsewhere, is well known. The Cretaceous sea, which extended from the Gulf of Mexico to the Arctic Ocean, covering the whole western plains and plateau region, and thus dividing the American continent into two, — an eastern Appalachian continent and a western or basin region continent, — was abolished at the end of the Cretaceous, and replaced by great fresh-water lakes in the same region, and the continents became one. Moreover, it is probable that it was a period of wide-spread oscillation, that is, of upheaval and again of subsidence to the condition of things found at the beginning of the Tertiary. It is probable that the upheaval which destroyed the Cretaceous sea went much beyond the condition of things afterwards; that just at this interval the land was higher and larger than in the Tertiary; that, in short, this was again a *continental period*, and probably a period of greater cold than the subsequent Tertiary.

The change in physical geography, then, was immense, but in most places by bodily upheaval, not by crumpling of the strata; and therefore the usual sign of such change, namely, unconformity, is often wanting. The change of climate all over the American continent was no doubt very great, and the change in organic forms correspondingly great everywhere and in all departments; but this was especially true of all water-inhabiting species in the region of the old Cretaceous interior sea, for here there was a transition, not only in climate but from salt to fresh water through the intermediate condition of brackish water. The Cretaceous marine species rapidly disappeared, partly by extermination and partly by transmutation into fresh-water species, as has been observed, recently, to take place in some crustaceans under this change of conditions.[1] The Tertiary fresh-water species quickly appeared, partly by transmutation from the previous marine species and partly by transportation in various ways from other fresh-water lakes. But all this occurred in some places without the slightest break in the continuity of the strata.

The great change of climate and other physical conditions perhaps sufficiently explain the change in *invertebrate* species, but it is impossible to account for the somewhat sudden appearance of mammals in the lowest Tertiary, except by *migration* from other regions where they had existed in late Cretaceous times, having originated there by derivation in the usual way. That marsupials existed somewhere in Cretaceous times (though possibly not in America or Europe) there can be no doubt; for they lived, we know, in the preceding Jurassic and the following Tertiary, and they exist *now*. It is from these rather than from Cretaceous reptiles that Tertiary mammals were doubtless derived; and this derivation took place probably at rapid rate in the latest Cretaceous or during the lost interval, in some unknown locality, whence they migrated into the Tertiary lake region of the United States during the interval. This migration came most probably from Northern Asia, for it must be remembered that the interval was a continental period, and therefore probably a period of broad land connections between Nearctic and Palæarctic regions. The complete examination of the uppermost Cretaceous of different portions of Asia will probably reveal the immediate progenitors of the early Tertiary mammals of Europe and America. This introduces us to a most important element of rapid local faunal change, especially in higher animals, namely, *migrations*. If we do not dwell longer now on this, it is only because we shall have to recur to it again.

---

[1] Arch. des Sciences, November, 1875, p. 284.

I have preferred, thus far, to speak of *general* evolution-changes of organisms, whether slow or rapid, as produced by varying pressure of external conditions, and of the most striking *local* changes by migrations from other regions, where the apparently suddenly-appearing species had previously existed, having originated there by evolution in the usual way. I have chosen, thus far, to represent the organic kingdom as lying, as it were, *passive* and plastic under the molding hands of the environment. I have done so because it is in accordance with true method to exhaust the more obvious causes of evolution before appealing to the more obscure and doubtful.

It is possible that general movements affecting alike all classes may be accounted for in this way alone. But there are many facts in the evolution of the organic kingdom, especially the sudden appearance of new forms in the quietest times, which can hardly be thus explained. There seem to be *internal* as well as *external* factors of evolution. Again, the internal factors may be either in the form of *tendencies* to change or of *resistance* to change. Of these, however, the latter seems to be most certain. There may be in the organic kingdom an "*inherent tendency*" to change in special directions, similar to that which directs the course of embryonic evolution, — a tendency, in the case of the organic kingdom, inherited from physical nature from which it sprang, as in the case of the embryo it is inherited from the organic kingdom through the line of ancestry. This cause, however, is too obscure, and I therefore pass it by.

But whether or not there be any such inherent tendency to change, there certainly is an inherent tendency to *stability*, — to persistence of organic form. If there be no inherent force of progress, there certainly is an inherent force of *conservation* greater in some species than in others. It seems probable that in many of the more rigid types this stability is so great, and therefore variation of offspring so slight, that progressive change of form is too slow to keep pace with change of external conditions, especially in critical periods. If this be so, then an organism may be regarded as under the influence of two opposing forces: the one conservative, the other progressive; the one tending to equilibrium, the other to motion; the one to permanence, the other to change of form; the one static, the other dynamic; the one internal, *the law of heredity*, the other external, the *pressure of a changing environment.* Under the influence of two such forces, the one urging, the other resisting, it is evident that even with steady changes of external conditions the change of organic forms would be more or less paroxysmal. Other kinds of evolution, physical and social, evidently advance paroxysmally from this cause. As, therefore, in the gradual evolution of earth-features there are periods of comparative quiet, during which the forces of change are gathering strength but produce little visible effect, being resisted by crust-rigidity, and periods when the accumulating forces finally overcome resistance and determine comparatively rapid changes; as in social evolution there are periods in which forces of social change are gathering strength but make no visible sign, being resisted by social conservatism, — rigidity of the social crust, — and periods in which resistance gives way and rapid changes occur, so also in the evolution of the organic kingdom the forces of change, that is, pressure of changing environment, may accumulate but make little impression, being resisted by the *law of heredity* — of *like producing like* — or type-rigidity, until, finally, the resistance giving way, the organic form breaks into fantastic *sports* which are at once seized by natural selection, and rapid change is the result.

Some persons seem to think that paroxysmal evolution is inconsistent with the uniformity of nature's laws. On the contrary, it is in perfect accord. Laws and forces are indeed uniform, but phenomena are nearly always paroxysmal. The forces of volcanoes and earthquakes, of lightning and tempests, are uniform, but the phenomena are paroxysmal. Winds at the earth's surface, where the resistance is great, *blow in puffs.* A thin sheet of water over a smooth sloping surface *runs in waves.* The law may be illustrated in a thousand ways. In all cases where an accumulating force is opposed by a constant resistance, we have phenomena in paroxysms.

But whatever be the cause, the *fact* of paroxysmal movement of organic evolution is undoubted. All along the course of geological history, from beginning to end, even when the times were quietest, where the record is fullest and apparently without any missing leaf, species come and go and others take their place, and yet only rarely do we find any transition steps. If this were merely once or twice or thrice, or to any extent exceptional, it might be explained by loss of record here and there, but it occurs thousands and tens of thousands of times. Now, if evolution moves only at uniform rate, if it takes one hundred thousand years to transmute one species into another (as it certainly does when evolution is moving at its usual rate), if there are at least one hundred thousand steps (represented each, of course, by a whole generation of many individuals) between every two consecutive species, it is simply incredible that all the individuals representing the intermediate steps, so infinitely more numerous than the species they connect, should be so generally, almost universally, lost. But the phenomena, as we find them, are easily understood if a few generations represent the transition step, and many generations the permanent form.

A similar rapid, almost sudden, appearance and extinction of *genera, families*, and higher groups at certain horizons are also common. In these cases the intermediate steps of transition are often found, and constitute, in fact, the chief demonstrative evidence of the truth of evolution. But the difficulty on the assumption of a uniform rate of evolution is none the less here, for the time required to evolve a new genus or a new family is, of course, immensely greater than in the case of a new species.

We will illustrate the difficulties of the ordinary view by one striking example. In the Upper Silurian, in the midst of a conformable series, — where if there be any break, any lost record, surely it must be very small, — appear suddenly, without premonition, *fishes ;* not a connecting link between fishes and any form of invertebrates, but perfect, unmistakable fishes. Here we have, therefore, the appearance not only of a new class, but of a new sub-kingdom or type of structure, *Vertebrata.* Now, to change from any previously existing form of invertebrate, whether worm, crustacean, or mollusk, into a vertebrate, by a series of imperceptible steps represented by successive generations, — steps so imperceptible that it would take one hundred thousand of them to advance from one intermediate species to another, — would require an amount of time which is inconceivable to the human mind, and a number of steps, each be it remembered, represented by thousands of individuals, which can scarcely be expressed by figures. And yet we must believe that these innumerable transitional forms, each represented by innumerable individuals, are all lost, and that this prodigious time shows no evidence in the rocky record. If this case were exceptional we might possibly admit that fishes appeared in Great Britain by migration (as they probably did), but only after having previously existed untold millions of ages somewhere else; but similar cases are too common to be explained in this way.

Now the whole difficulty disappears, — we avoid the incredible imperfection of the geological record (imperfect at best); we avoid also the necessity of extending geological time to a degree which cannot be accepted by the physicist, — if we admit that the derivation of one species from another is not necessarily by innumerable imperceptible steps, but may sometimes be by a *few decided steps;* and that the same is true for the origin of new genera, families, orders, etc.; in a word, that there are in the history of evolution of species genera, families, orders, etc., and of the organic kingdom *periods of rapid movement.* When the whole organic kingdom is involved in the movement, then we call the period *critical,* and the record of it is often lost.

Thus, on the supposition of such rigidity or resistance to change in organic forms, varying in degree in different species and in different genera, families, orders, etc., a rigidity, also, *increasing by accumulated heredity so long as conditions remain unchanged,* it is evident that, in times of perfect tranquillity all species grow more and more rigid. In times of very gradual change the more plastic species change gradually *pari passu,* while the more rigid species change paroxysmally, now one, now another, as their resistance is overcome. Finally, in times of revolution nearly all forms yield to the pressure of external conditions and change rapidly, *only the very exceptionally rigid being able to pass over the interval to the next period of readjusted equilibrium.*

Thus, for example, the great and wide-spread changes of physical geography which occurred at the end of the Carboniferous, appropriately called in this country the *Appalachian revolution,* were the death-sentence of the long-continuing and therefore rigid Palæozoic types. But the sentence was not immediately executed. The Permian represents the time between the sentence and the execution, — the time during which the more rigid Palæozoic forms continued to linger out a painful existence in spite of changed and still changing conditions. But the most critical time — the time of most rapid change, the time of actual execution — was the *lost interval.* Only a very few most rigid forms pass over this interval into the Trias.

The Quaternary, a Critical Period. We have given examples of several general unconformities, the signs of wide-spread oscillations of the earth-crust, attended with increase and decrease of land, and therefore with great and wide-spread changes of climate and other physical conditions, and also with great and rapid changes of organic species. These times of general oscillation are therefore the natural boundaries of the Eras or primary divisions of Time. We have called them critical periods, transition periods, periods of revolution, because they are times of rapid change, both in the physical and the organic world, — a change overthrowing an *old* and establishing a *new* order of things. They are also times of *lost record.* We have seen that these critical periods, in comparison with the preceding and succeeding, are *continental periods*, and it is for this reason that their record is usually lost.

Now, the Quaternary is such a critical or transition period, marking the boundary between two great eras. The Quarternary is also a period of great and wide-spread oscillations, with increase and decrease of land, — a period of upheaval, erosion, down-sinking, to rise again slowly to the present condition. The early Quaternary was, therefore, to a marked degree a continental period. Here also we have newer rocks lying unconformably on the eroded edges of an older series — river sediments in old river-valleys, marine sediments in fiords; in other words, we have unconformity on a grand scale. Also, in connection with these oscillations, we have great changes in physical geography, and corresponding and very wide-spread changes in climate, and consequently corresponding rapid changes in organic forms. Here, then, we have all the characteristics of one of the boundaries between the primary divisions of time. We have a transition or *critical* period, — a period corresponding to one of the lost intervals; only in this instance, being so recent and being also less violent than the preceding ones, *it is not lost.* From this it follows that the study of the Quaternary ought to furnish the key which will unlock many of the mysteries which now trouble us. Some of the problems which have been or will be explained by study of the Quaternary we will now briefly mention.

I. *Changes of Species not sudden.* If the Quaternary were lost, and we compare the Tertiary rocks with the unconformably overlying recent rocks, and the Tertiary mammals with those now living, how great and apparently sudden seems the change!

How like to a violent extermination and re-creation! But the Quaternary is fortunately not lost, and we see that there has been no such wholesale extermination and re-creation, but only gradual though comparatively rapid transition.

II. *Migration One Chief Cause of Change.* But what is still more important, we are able to trace with something like certainty the cause of these rapid changes, and we find that in the higher animals, chief among these causes have been *migrations*, — migrations enforced by changes of climate, and migrations permitted by changes of physical geography opening gateways between regions previously separated by impassable barriers. This point is so important that we must dwell upon it. Only an outline, however, of some of these migrations and their effects on evolution can be given in the present condition of knowledge.

During Miocene times, as is well known, evergreens, allied to those now inhabiting Southern Europe, covered the whole of Europe as far north as Lapland and Spitzbergen. In America, Magnolias, Taxodiums, Libocedrus, and Sequoias very similar to, if not identical with, those now living on the Southern Atlantic and Gulf coasts and in California were abundant in Greenland. Evidently there could have been no *Polar ice-cap* at that time, and consequently no arctic species unless on mountain tops. During the latter part of the Pliocene the temperature did not differ much from the present; the Polar ice-cap had therefore commenced to form, with its accompaniment of arctic species. With the coming on of the *Glacial epoch*, the polar ice and arctic conditions crept slowly southward, pushing arctic species to Middle Europe and Middle United States, and sub-arctic species to the shores of the Mediterranean and the Gulf. With the return of more genial climate, arctic conditions went slowly northward again, and with them went arctic species slowly migrating, generation after generation, to their present arctic home.

Similarly, molluscous shells migrated slowly southward and again northward to their present position. But *plants* and some terrestrial invertebrates, such as *insects*, had an alternative which shells had not, namely, that of seeking arctic conditions also *upward* on the tops of mountains. Many did so, and were left stranded there until now. It is in this way that we account for the otherwise inexplicable fact that Alpine species in Middle Europe are similar or even largely identical with those in the United States, and also with those now living in arctic regions. These species were wide-spread all over Europe and the United

States in Glacial times; and while some of them afterward went northward to their present home, some in each country sought arctic conditions in Alpine isolation. This explanation, which has been long recognized for plants, has been recently applied by Mr. Grote to arctic insects found on the top of Mt. Washington and the mountains of Colorado.[1]

Undoubtedly changes of climate during this time enforced similar migrations among mammals also. But it is evident that while plants and invertebrates might endure such modifications of climate and such enforced migrations with little alteration of form, the more highly organized and sensitive mammalian species must be either destroyed or else must undergo more profound changes. Moreover, the opening of land connections between regions previously isolated by barriers would be far more quickly taken advantage of by mammals than by invertebrates and plants. The migrations of plants are of necessity very slow, that is, from generation to generation. The migrations of mammals, too, so far as they are *enforced* by changing climate, are of a similar kind; but the voluntary migrations of mammals, *permitted* by removal of barriers, may take place much more rapidly, even in a few generations. This introduces another element of very rapid local change, namely, the *invasion* of one fauna by another equally well adapted to the environment, and the struggle for life between the invaders and the autochthones.

For example: in America during the Glacial epoch, coincidently with the rigorous climate, there was an elevation of the continent, greatest in regions of high latitude, but also probably great along the line of the Mississippi River; for in this region it extended southward even to and beyond the shores of the Gulf. Professor Hilgard has shown that the elevation at the mouth of the Mississippi River was at least four hundred and fifty to five hundred feet above the present condition. Until the Glacial times the two Americas were certainly separated by sea in the region of the Isthmus, as shown by the Tertiary deposits there. This barrier was removed by upheaval during the Glacial epoch, and a far broader connection existed *then* than now. Through this open gate-way came the fauna of South America, especially the great Edentates, into North America. Similarly a broad connection then existed between America and Asia in the regions of the shallow sea between the Aleutian Isles and Behring Strait. Through this gate-way came an invasion from Asia, including probably the mammoth. With this invasion probably came also man. It seems probable, therefore, that the earliest remains of man in America will be found on the Pacific coast.

---

[1] This application, with reference to Mt. Washington and other arctic insects in America, was previously made by Prof. A. S. Packard, Jr., in the Memoirs of the Boston Soc. Nat. Hist., i. p. 256. 1867. — EDS.

Also the great Pliocene lake, which stretched from near the shores of the Gulf far into British America, and possibly into arctic regions, and formed a more or less complete barrier to the mammalian fauna east and west, *was abolished* by upheaval, and free communication was established. It is impossible that all these changes of climate and all these migrations, partly enforced by changes of climate and partly permitted by removal of barriers, and in this latter case especially attended with the fiercest struggle for life, should not produce rapid and profound changes in the mammalian fauna.

In Europe the process has been more accurately studied and is better known. In Quaternary times at least four different mammalian faunæ struggled for mastery on European soil. (1.) The Pliocene autochthones. (2.) Invasions from Africa by opening of gate-ways through the Mediterranean: one by way of Italy, Sicily, and Malta, and one by Gibraltar, both of which have been again closed. (3.) Invasions from Asia, by removal of a great sea barrier connecting the Black and Caspian seas with the Arctic Ocean. This gate-way has remained open ever since. (4.) Invasions from arctic regions, enforced by changes of climate. Probably more than one such invasion took place; certainly, one occurred during the second Glacial epoch. The final result of all these climatic changes and these struggles for mastery was that the Pliocene autocthones, adapted to a more genial climate, were mostly destroyed or else driven southward with some change into Africa: the African invaders were driven back also into Africa, and with some Pliocene autocthones isolated there by subsidence in the Mediterranean region closing the southern gateways, and still exist there under slightly modified forms; the Arctic invaders were again driven northward by return of more genial climate, and there exist to this day; while the Asiatics remained masters of the field, though greatly modified by the conflict. Or perhaps, more accurately, we might say that the existing European mammalian fauna is a resultant of all these factors, but the controlling factor is the Asiatic. With the Asiatic invasion came man, and was a prime agent in determining the final result.

Thus, regarding the Tertiary and the Present as consecutive eras, and the Quaternary as the transition or critical period between, then, if the record of this period had been lost, corresponding with the unconformity here found, we should have had here an enormous and apparently sudden change of mammalian species. Yet this change of fauna, as great as it is, is not to be compared with that which occurred between the Archæan and Palæozoic, or between the Palæozoic and Mesozoic, or even that between the Mesozoic and Cænozoic; for the change during the Quaternary is mostly confined to species of the higher mammals, while the change during previous critical periods extended to species of all grades, and not only to species, but to genera, families, and even orders. We conclude, therefore, that *the previous critical periods or lost intervals were far longer than the whole Quaternary; or else that the rate of evolution was far more rapid in these earlier times.*

To sum up, then, in a few words, the general formal laws of evolution-change throughout the whole history of the earth: —

(1.) Gradual, very slow changes of form everywhere under the influence of all the factors of change, known and unknown: for example, pressure of changing physical conditions whether *modifying the individual* (certainly one factor), or *selecting the fittest offspring* (certainly another factor); improvement of organs by use and the improvement inherited (certainly a third factor), and perhaps still other factors yet unknown. This general evolution by itself considered would produce similar changes everywhere, and therefore would produce geological faunæ, but not geographical diversity. Determination of a geological horizon would in this case be easy, because fossil species would be everywhere identical.

(2.) Changes in different places and under different physical conditions, taking different directions and advancing at different rates, give rise to *geographical faunæ.* This, if there were nothing more, would produce far greater geographical diversity and more complete localization of faunæ and floræ than now exists, — so great that the determination of a geological horizon would be impossible.

(3.) The force of change resisted by heredity, in some species and genera more than in others, determines paroxysms of more rapid movement of general evolution, affecting sometimes species, sometimes genera or families. The sudden appearance of species, genera, families, etc., in quiet times is thus accounted for.

(4.) *During critical periods*, oscillations of the crust, with rapid changes of physical geography and climate, determine a more rapid rate of change in all forms: first, by *greater pressure of physical conditions;* and, second, by *migrations* partly enforced by the changes of climate and partly permitted by removal of barriers, and the consequent *invasion* of one fauna and flora by another and *severe struggle* for mastery. This would tend to *equalize again* the extreme diversity caused by the second law; but the effect would be more marked in the case of animals than plants, because voluntary migrations are possible only in this kingdom. Hence it follows that *a geological horizon is far better determined by the fauna than by the flora.*

III. *Historic Value of the Present Time.* Most geologists regard the Present as one of the minor subdivisions of the Cænozoic era, or even of the Quaternary period. More commonly the Quaternary and Present are united as one age — the age of man — of the Cænozoic era. The Cænozoic is thus divided into two ages: the age of mammals commencing with the Tertiary, and the age of man commencing with the Quaternary; and the Quaternary subdivided into several epochs, the last of which is the Present or Recent. But if the views above expressed in regard to critical periods be correct, then the Present ought not to be connected with the Quaternary as one age, nor even with the Cænozoic as one era, but is itself justly entitled to rank as one of the *primary divisions* of time, as one of the great eras separated like all the other eras by a critical period; less distinct it may be, at least as yet, in species than the others, the inaugurating change less profound, the interval less long, but dignified by the appearance of man as the dominant agent of change, and therefore well entitled to the name *Psychozoic* sometimes given it. The geological importance of the appearance of man is not due only or chiefly to his transcendent dignity, but to his importance as an agent which has already very greatly, and must hereafter still more profoundly, modify the whole fauna and flora of the earth. It is true that man first appeared in the Quaternary, but he had not yet established his supremacy; he was still fighting for mastery. With the establishment of his supremacy the reign of man commenced. An age is properly characterized by the *culmination*, not the first appearance, of a dominant class. As fishes existed before the age of fishes, reptiles before the age of reptiles, and mammals before the age of mammals, so man also appeared before the age of man.

We the rd the Cænozoic and Psychozoic as two consecutive the Quaternary as the critical, revolutionary, or tra riod between. But since the record of this last critical period is not lost, and we must place it somewhere, it seems best to place it with the Cænozoic era and the mammalian age, and to commence the Psychozoic era and age of man with the completed supremacy of man, that is, with the Present epoch.

BERKELEY, CALIFORNIA, *March* 15, 1877.

RECENT LITERATURE.

BREHM'S ANIMAL LIFE.[1] — A second edition of Brehm's well-known German work on the animal kingdom is now in course of publication, to be issued in about a hundred parts, published weekly or fortnightly, forming a series of volumes of unusual attractiveness and interest. The author tells us that it is really a new work under an old title, having been rewritten and enlarged. While the first volume of the first series treats of the mammals from the apes down to the family of dogs, succeeding volumes will treat of the other mammals and of the reptiles and fishes. These will be written by Dr. A. E. Brehm, the well-known naturalist, while those on the articulated animals will be written by Prof. E. L. Taschenberg, of Halle, and the mollusks will be treated of by Prof. Oscar Schmidt, of Strasburg. What provision is to be made for the other invertebrate animals is not yet announced.

The work is of a general nature, not designed for the special zoölogical student or for children, but for those who wish to gain a knowledge of the principal forms of animal life, their habits and distribution. There are no troublesome, perplexing anatomical or embryological details, save wood-cuts of skeletons, in word or picture, no foot-notes, and the style is easy, sprightly, and often colloquial. It is apparently a popular work in the best sense of the word, and should be well patronized in this country, if for no other reason than for the wealth of wood-cuts, both full-page and textual, which alone, to those ignorant of German, would make it of lasting value. The illustrations are nearly all new to us, and in very many, we suppose most, cases are drawn from life by such artists as R. Kretschmer, G. Mutzel, and E. Schmidt, with the greatest apparent fidelity.

The plan of the work is excellent. After an introductory chapter on life in its totality, the apes are described, — man, the type of the first sub-order of Primates, being referred to only incidentally in comparison with

---

[1] *Brehm's Thierleben.* Allgemeine Kund, des Thierreichs. Grosse Ausgabe. Zweite umgearbeitete und vermehrte Auflage. Erste Abtheilung, Säugethiere. Erster Band. Leipzig Verlag des bibliographischen Institute. 1876. 8vo, pp. 706. New York: B. Westermann & Co. 40 cents a part; 12 parts to a volume.